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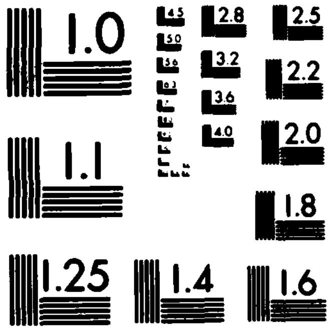

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A LASER RANGE-FINDER WITH A RANGING ACCURACY OF ±0.5m

by

Zhou Zhengwen, Zhao Weiming, et al

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A LASER RANGE-FINDER WITH A RANGING ACCURACY OF ±0.5m

Zhoy Zhengwen Zhao Weiming Cai Genxin Lu Quirong

(Shanghai Institute of Optics and Fine Mechanics, Academia Sinica)

Abstract: This paper describes a compact pulsed laser range-finder with a ranging accuracy of ±0.5m and a maximum range of 5000m. Some factors affecting the ranging accuracy and the methods for improvement are discussed and some measurement data for this range finder are given.

A series of factors have limited the improvement of miniaturized /46 pulsed laser range finder accuracy. These factors are: crystal high pressure interference; effect of laser wave front, development of high speed counter, etc. Among these, the more outstanding one is the effect of laser wave front. Each of these factors and the solutions adopted by us are discussed below. We are able to improve the ranging accuracy to 0.5 meters.

1. Crystal High Pressure Interference

In most miniaturized laser range finders, crystals are used for Q tuning, but a very strong interference is induced when the crystal high pressure is being increased or reduced. This interference will enter the highly sensitive receiver-amplifier through the circuit system. It is very close to the laser-emission signal with only a separation of about 100 millimicroseconds. (See Figure 1). It is difficult to resolve this problem with the well-known time-expansion return to zero technique. Of course, this interference may be greatly suppressed by adopting good shielding and other anti-interference measures, but complicated technical measures will have to be used.

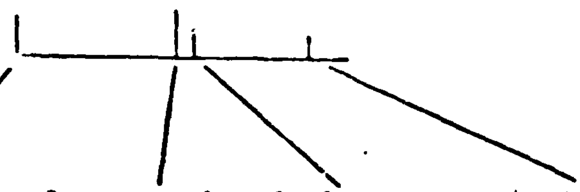

Figure 1.
Key: 1--xenon tube trigger 2--crystal high pressure 3--laser emission signal 4--laser return signal

We use a double-channel input format with time channel selection on the range finder with 1 meter and 0.5m accuracy, i.e., the laser emission signal and the return signal enter the counter separately. We use a single silicon phototube to receive the laser emission signal, and to open the counter gate through an emitter follower. Because there is no amplifier in this channel, therefore the crystal high pressure interference is small and will not be able to trigger the counter. On the output side of the receiver-amplifier, there is still a very strong crystal high pressure interference but it will not affect the counter. In this method, there will be an effect due to the time delay of the receiver-amplifier but, in practice, it only causes a fixed error. Its instability is not enough to affect the accuracy at 1 m to 0.5 m. /47

2. The effect of the laser waveshape front

The half width of the output laser wave from the laser used in a miniature laser range finder is generally 7-8 millimicrosecond The wave front is approximately the same. After hitting the target, the laser light will be reflected. Since it is a scattered reflection, the wave front of the returned wave received will be worse. From actual measurement with an oscilloscope, the wave front of the returned wave for a chimney is 16 millimicrosecond. The returned signal is used to close the counter gate after the receiver-amplifier. Apparently, there will be a time difference of 16 millimicrosecond whether the counter is closed at the base of the returned signal

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(for a sufficiently strong returned signal, the amplifier will be in the saturated state) or at the top (for distance at effect limitation). This is equivalent to an error of 2 meters.

To eliminate the effect of the laser wave front, the first method is to make the returned wave amplitude large enough so that the receiver amplifier is constantly in a saturated state to guarantee that the counter is always closed at the base of the returned wave. The second method is to compress the width of the wave form to reduce the wave front. This, however, must involve the increase in the volume of the laser,thus violating the principle of miniaturization. The third method is to use a constant ratio discriminator. A so-called constant ratio discriminator always output a pulse at a fixed value of amplitude ratio no matter how the amplitude of the input signal varies. After passing the returned signal through a constant ratio discriminator, the output pulse is then used to close the gate of the counter, so as to eliminate the effect of the wave front. The ratio we selected is 1/2, hence it is known as the half amplitude discriminator.

For an explanation of the function of the half amplitude discriminator, Figure 2 is to be consulted. The premise here is that the signal only varies its amplitude while keeping the wave front unchanged. (a) shows that with the normal method, the closing voltage level of the counter is constant. We can see that, following the variation of the signal amplitude, the counter closing time is at respectively t_1, t_2 and t_3. The variation in the closing time reflects that the distance value is changing. (b) shows that with the half amplitude discriminator, no matter how the signal amplitude varies, the half amplitude discriminator always outputs a pulse at t_0 when the signal amplitude is 1/2 to close the gate of the counter.

The block diagram and the working principle of the half amplitude discriminator are shown in Figure 3. The input signal travels along 2 paths. There is no time delay in one path, but a decay of 1/2. Where there is a time delay in the other path, the delay time is about half of the signal wave front. Both paths lead to

the high speed comparator. Then from the crossing point O of the 2 signal, the comparator inverts and outputs a pulse.

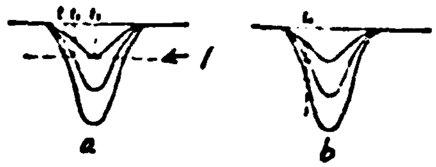

Figure 2.

Key: 1--counter gate closing voltage level

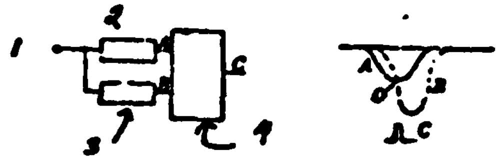

Figure 3.

Key: 1--signal; 2--decay 1/2; 3--time delay; 4--high speed comparator

The half amplitude discriminator circuit developed by us is very simple. With ECL integrated circuit, the output voltage level just matches the ECL integrated circuit of the high speed counter at the next stage. Experiment indicated that when the amplitude value of the input signal with wave front 10 millimicrosecond changes from 100 millivolt to 1200 millivolt, the error of the half amplitude discriminator output pulse from the half amplitude point is less than 1 millimicrosecond. Such a half amplitude discriminator is enough to guarantee the ranging accuracy of 0.5 meters. For higher ranging accuracy, the circuit needs to be more complex.

From Figure 2(b), it can be seen that to guarantee the ranging accuracy, the wave front of the input signal to the half amplitude discriminator should not vary, i.e., the laser return signal is not amplitude-limited after being amplified by the receiver-amplifier. This requires the receiver-amplifier to have a fairly wide dynamic range. This may be achieved with the technique of floating point amplification but the circuit is complicated and bulky. We use the photo multiplier tube as the receiving element with its output directly applied to the half amplitude discriminator.

3. 300 Megahertz High Speed Counter

The range counter is a very important part in a laser range finder. For a range finder with 0.5 m ranging accuracy, the counting speed of the counter is required to reach 300 megahertz. To satisfy the requirement of miniaturization of the complete system, as well as high stability, we have integrated the 300 μh counter. The first few stages of the counter are composed of ECL IC's. When the frequency drops to the neighborhood of 15 μh, the later stages are composed of TTL integrated circuits. /48

For the 300 μHz counter, the clock frequency should be 300 μHz if normal counting method is used and the speed of the first stage element of the counter should also reach 300 μHz. Although the maximum speed of ECL integrated circuit has already reached 500 μHz, its stability, especially its thermal stability, is still complicated by many problems. Hence they are not suitable for field use under adverse conditions. Besides, their cost is also high. The ECL10K series is probably the circuit with the best stability characteristics, but they have only a highest speed of 160 μhz. We used the bi-directional counting method to build the first stage of a 300 μhz counter. The element used is the 160 μhz ECL circuit, with a clock frequency of 150 μhz.

The block diagram of the 300 μhz distance counter is shown in Figure 4. Experiments indicate that the accuracy of this counter is completely satisfactory.

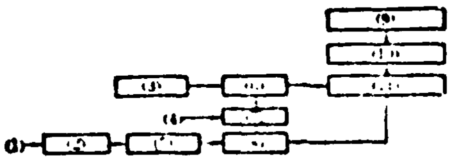

Figure 4.

Key: 1--return wave; 2--photo multiplier tube; 3--150 mhz clock; 4--laser emission signal; 5--half-amplitude discriminator; 6--gate; 7--gate control; 8-- recorder; 9--display; 10--memory; 11--counter.

4. Actually Measured Data

Several sets of measured data are shown below for the laser range finder with ranging accuracy 0.5m. The laser used is double 45^{o} $LiNbO_3$ crystal tuned Q Nd: YAG laser. The output power is 10 m watt. The receiving telescope diameter is ø60 and the voltage of the photo multiplier tube is 1150 v.

4.1 Distance measurement for 4 fixed targets.

Each target was measured over 100 times. The distances measured are respectively: 515.5-5.6-0m, 2222.0-2222.5m, 4904.5-4905.0m, 5679.0-5679.5m. The jump is 0.5m for all cases.

4.2 Experiment on the effect of the half amplitude discriminator.

To obtain a large returned wave signal, we selected a nearby target and covered the opening of the receiving telescope with dark paper to make the wave amplitude vary. An oscilloscope is used for monitoring.

Table 1 gives the relationship between measured distance and the variation in the wave amplitude after using the half amplitude discriminator. We can see that the distance remains unchanged for a 10-time variation in the wave amplitude. Table 2 gives the

relationship when the half amplitude discriminator is connected as an amplifier. For returned wave amplitude in the range from 500 millivolt to 300 m V, the amplifier is not saturated. The distance value varies over 2 meters when the input signal varies by 5 fold. This is caused by the wave front of the returned wave signal. When the returned wave is larger than 200 mV, the amplifier is saturated and the distance value becomes unchanged.

TABLE 1.

mV (1)	m (2)
50	515.5~516.0
80	515.5~516.0
150	515.5~516.0
250	515.5~516.0
600	515.5~516.0

Key:1-Returned wave amplitude (millivolt);2-Distance (meter).

TABLE 2.

mV (1)	m (2)
50	516.5~517.0
70	515.5~516.0
100	515.0~515.5
300	514.5~515.0
600	514.5~515.0

Key:1-Returned wave amplitude (millivolt);2-Distance (meter).

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[2]. W.T. Rhoades; Electronic Design, 1964, 12, No. 20,48.

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